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The Patent Office

Cardiff Road
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1. Your reference

C548/W

2. Patent application number
(The Patent Office will fill in this part)

9912893.6 -4 JUN 1999

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

UNOVA U.K. Limited
26 Temple Street
Aylesbury
Bucks HP20 2RQ

Patents ADP number *(if you know it)*

7728529001

If the applicant is a corporate body, give the country/state of its incorporation

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4. Title of the invention

Surface forming of metal components

5. Name of your agent *(if you have one)*

Keith W Nash & Co

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

90-92 Regent Street
Cambridge
CB2 1DP

Patents ADP number *(if you know it)*

1206001

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
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Yes a)

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Continuation sheets of this form	0
Description	9
Claim(s)	0
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Priority documents

Translations of priority documents

Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*

Request for preliminary examination and search *(Patents Form 9/77)*

Request for substantive examination *(Patents Form 10/77)*

Any other documents *(please specify)*

11. I/We request the grant of a patent on the basis of this application.

Signature Date

Keith W Nash & Co, Agents

12. Name and daytime telephone number of person to contact in the United Kingdom

Mr Nash (01223) 355477

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C548/W

Title: Surface forming of metal components.

Field of invention

This invention concerns the formation of surface finishes of metal components and applies both to internal and external surfaces.

Background to the invention

The surfaces of metal components hitherto surface-finished by a grinding process, have been specified by means of measurements which can be performed on the components as they are manufactured.

Typically these measurements have involved size tolerance at a particular position along the length of the component, an acceptable variation in the height of peaks to troughs in the surface when measured along a single line along the component, known as the Ra measure, and the bearing ratio of the peaks and troughs at one or more depths from the peaks. This last measurement may be required to lie between a maximum and a minimum percentage of the length of the line.

Overall flatness has often been measured in terms of the percentage of the area of the surface which will be inked by a standard bluing gauge.

All other things being equal, provided the measurements on production components fall within the specification set down as acceptable by the designer, the components will be expected to function correctly for the purpose they are intended. Thus for example surface finish specifications may be laid down for the bores in fuel injectors for diesel engines and for the cones for synchronous meshing of gears in transmission units.

Generally the surface finishing of such components has been achieved by grinding processes which although superficially leaving a very smooth surface finish, in fact leave a pitted surface (at the micron level) since the removal of the metal is achieved by each piece of grit in the surface of the grinding wheel gouging out a tiny portion of the metal, with the relative rotation of the wheel and the component. The grit contact with the metal is relatively random and arbitrary since the grit is not uniform in size and distribution and the result is a surface having a large number of tiny pockets relatively randomly distributed over the area of the surface.

It has been proposed to replace the grinding finishing step with precision turning, sometimes referred to as hard turning, and it is an object of the present invention to provide a process and apparatus for achieving a surface finish when turning, which to a first approximation is within the specification laid down for the component when finished by grinding. In this way turned components can be compared alongside components produced by conventional techniques.

In addition if as may be the case the life and/or functionality of certain components is dependent on the type of surface produced by grinding, the method of the invention will go some way to ensuring that the life and/or functionality of such components when formed by turning, is similar to that of the ground components.

Summary of the invention

According to one aspect of the present invention in a turning process in which a cutting tool engages the surface of a rotating component so as to remove a helix of metal therefrom as a result of synchronisation of the relative axial movement of the tool and the component and the rotation of the latter, at least the depth of cut achieved by the tool and component engagement is under the control of a programmed computer.

The computer may also be programmed to control the speed of rotation of the component.

The computer may also be programmed to control the relative axial movement between the tool and the component.

Typically the tool is moved axially relative to the component so as to progress the point of engagement between the tool and the surface of the component along the length of the latter as the component rotates.

Preferably the computer is programmed so as to synchronize the rotation of the component and the axial movement of the tool so that the locus of the point of engagement of the tool and the component is a helix.

Preferably the axial movement of the tool is synchronised with the rotation of the component so that the angle of the helix is such as to just advance the tool by the thickness of its cutting tip during each revolution, so that not only is a continuous helix of metal peeled away from the surface of the component as the machining progresses but a smooth surface is left behind.

If a taper is required in the component the depth of cut may be increased progressively with axial advance of the tool relative to the component, however the increasing depth of cut would still normally be controlled so as to produce a smooth surface, albeit of progressively reducing diameter.

In accordance with an important aspect of the invention, in a process of producing a component by metal removal by turning whilst the surface of the component is engaged by the tip of a cutting tool, so as to progressively remove a helix of metal from the surface of the component and thereby produce at least in the region of the cut a cylindrical surface the radius of which is determined by the position of the tool relative to the axis of rotation of the component, and in which the tool is under computer control at least as to its position for determining the

depth of cut and therefore the radius of the turned surface of the component, the computer is programmed to increase the depth of cut at intervals during the turning process so as to create a plurality of depressions in the turned surface of the component which have a marginally smaller radius of curvature than that of the surrounding turned surface.

The programming may be such as to increase the depth of cut during regularly spaced apart intervals.

The timing of the intervals may such that at least one depression is created during at least a part of each revolution of the component.

The timing may be such as to produce a plurality of depressions around each revolution of the component.

The timing of the intervals may be adjusted from one revolution to the next so that depressions do not become aligned parallel to the axis of the component.

The timing of the intervals may be selected so as to produce a regular or random or pseudo random pattern of depressions in the component surface.

Each interval may be of the same duration so that each depression is of the same extent, or a variation may be introduced into the duration of each of the intervals so that the depressions are of correspondingly different size.

In a preferred method each interval is arranged to extend over a plurality of consecutive revolutions of the component so that each resulting depression comprises an annular region of reduced diameter.

The transition between the turned surface of the component and each such annular depression may be gradual and itself may be generated during more than one revolution of the component, by

programming the computer to increase the depth of cut gradually over the said one or more revolutions during which the transition is to occur. At the other end of such an annular depression the computer programme may be arranged to reduce the depth of cut in a similar gradual manner over a corresponding number of revolutions of the component, back to that required to produce the turned surface of the component beyond the annular depression.

Where the component is to taper in overall diameter, the depth of cut instructions generated by the programme during the transitions and during the generation of each reduced diameter annular region must take this into account, so that diameter of the component is progressively reduced during the whole of the turning process.

Since the depressions are merely to break-up what would otherwise be a smooth surface produced by the turning process, the depth of each depression relative to the surrounding turned surface will normally need only to be very small. Differences in radius as between the base of each depression and the surrounding turned surface may be of the order of 1 micron or less. Where more significant surface break-up is desired the difference in radius may be of the order of 2 or 3 microns or more.

Depending on the properties required of the final surface the programming of the computer may be such as to produce relatively small but relatively deep depressions per unit area of the component surface or relatively large but relatively shallow depressions over the same surface area.

Likewise the number of depressions per unit area of the component surface may be adjusted to produce the desired characteristics in the final surface.

Where the final surface specification includes a bearing ratio vector requirement, the latter may be achieved by adjusting the rate of change of radius (diameter) at one or both ends of each

depression so that the required percentage of component material will exist at the specified depths relative to the peak diameter of the turned surface.

Where a bluing gauge percentage figure has to be complied with, the computer may be programmed to adjust the extent of the depressions relative to the remaining area of the turned component surface, so as to provide a sufficient overall area of turned surface which will be inked by the gauge, during the bluing test, relative to the overall area of the depressions, which will not normally become inked during the test.

Where the final surface is to be capable of being tested at any point along its axial length the programme should arrange that the depressions are evenly distributed over the overall surface of the component to ensure that measurements made on the component will tend to be the same wherever they are made.

Where the component is to be gauged as part of the control of the turning process, it is desirable that the precise positions of the depressions and any transitions between depression and main turned surface are known and to this end the programme advantageously organises the computer to store co-ordinates of the depressions and transitions or an algorithm of their generation, so that an appropriate correction can be made to the result of any gauged value of (say) diameter, or the position at which a gauge is to be applied may be determined in advance of the gauging step and the gauge or the component positioned accordingly before the measurement is made.

The invention also lies in a component when manufactured in accordance with a computer controlled hard turning method as proposed by the invention disclosed herein.

The invention also lies in a metal turning machine and computer control therefor programmed to perform a hard turning operation in accordance with the invention.

The invention also lies in a metal turning machine in combination with a computer based control system therefor, when programmed to perform a hard turning process on a component in accordance with the invention.

The invention also lies in a computer when programmed to control a metal working machine so as to perform a hard turning operation on a component such as described herein.

The invention also lies in a programme adapted to operate a computer so as to provide control signals for a metal working machine to cause the latter to perform a hard turning operation such as described herein.

The invention also lies in a computer programme for operating a computer so as to control a metal working machine to perform a hard turning operation on a component such as described herein, when stored on a data carrier.

The invention also lies in a computer programme for operating a computer, or a programmed computer, adapted to control the operation of a metal machining process involving the removal of metal from a rotating workpiece by the engagement therewith of the tip of a metal cutting tool at least the position of which is controlled by the said computer, and which as a result of synchronised relative movement between the tool and the workpiece, would produce a smooth machined surface thereon, wherein the programme serves to alter the instantaneous position of the tool so as to introduce into the otherwise smooth surface, during the machining process, plural spaced apart depressions for the purpose of simulating a surface typical of that which would be obtained thereon if the latter had been finished by grinding.

The invention also lies in a metal turning machine in combination with a computer based control system therefor, when programmed to perform a hard turning process on a rotating workpiece involving the removal of metal from the surface thereof by the engagement therewith of the tip of a metal cutting tool at least

the position of which is controlled by the said computer based control system, and which as a result of synchronised relative movement between the tool and the workpiece, would produce a smooth surface on thereon, wherein the programme serves to alter the instantaneous position of the tool during the machining process, so as to introduce into the otherwise smooth surface plural spaced apart depressions, for the purpose of simulating a surface typical of that which would be obtained on the workpiece if the latter had been finished by grinding.

The invention also lies in a method or apparatus as aforesaid which further comprises gauging and/or measuring the machined part during the machining process, to generate signals indicative of one or more dimensions of the machined part, and supplying the signals to the computer, to assist in the control of the machining process.

The invention also lies in a metal turning machine in combination with a computer based control system therefor, when programmed to perform a hard turning process on a rotating workpiece involving the removal of metal from the rotating workpiece by the engagement therewith of the tip of a metal cutting tool at least the position of which is controlled by the said computer based control system and which as a result of synchronised relative movement between the tool and the workpiece, would produce a smooth surface on the machined part, wherein the programme serves to alter the instantaneous position of the tool so as to introduce into the otherwise smooth surface of the machined part, plural spaced apart depressions during the machining process, for the purpose of simulating a surface typical of that which would be obtained thereon if the latter had been finished by grinding, and the machine includes at least one gauging or measuring device adapted to perform measurements on the machined part during the machining process, to generate signals indicative of one or more dimensions of the machined part, and means for conveying the signals to the computer as feedback signals indicative of how the process is progressing, to assist in the control of the process.

Examples of components which may be made in accordance with the invention.

Synchro cones for gearboxes have hitherto been formed by grinding to a particular surface and taper diameter specification. In a method in accordance with the invention, of hard turning such a component so as to have a surface which will fall within the previous specification for the component, using a computer controlled metal turning process as aforesaid, the computer was programmed so as to introduce into the turned surface annular depressions having a depth relative to the turned surface of 1 micron, at 1mm spacings along the axial length of the component, each depression extending over a total axial distance of 0.2mm with a transition involving a gradual change in radius extending over 0.07mm at each end of the annular region (within the 0.2mm length), so that the base of the depression, which lies a full 1 micron below the turned surface at either end, extended over less than the 0.2mm.

Other examples of a similar component involved the formation therein of similar annular depressions having the same overall axial extent and similar transitions, but with depths of 2 microns and 3 microns respectively, for comparison purposes.

Injector bores for fuel injectors for diesel engines have to be internally finished to a high accuracy and have hitherto been ground to achieve the desired finish and diameter. The invention offers an alternative manufacturing process for such injectors in which the bores are hard turned under computer control in accordance with the invention and have depressions formed in their internal surfaces to produce a surface having appropriate characteristics to conform to the original specification for the product when internally ground.